

HEAT EXCHANGER

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

[0001] The present invention relates to a heat exchanger such as a radiator for radiating heat of cooling water of an internal combustion engine used for an automobile and a heater core for heating and a condenser or evaporator for cooling in an air-conditioning system.

## 2. Description of the Related Art

[0002] The principal structure of an example of a heater core 41 serving as a heat exchanger for heating the air in a passenger compartment using the high temperature cooling water of an internal combustion engine in a conventional air-conditioning system is shown in FIG. 4. The overall configuration of the heater core 41 is substantially the same in appearance in FIG. 2 explained in detail later with reference to an embodiment of the present invention. In a conventional heater core 41, a plurality of flat tubes 42 formed into flat tubular shapes by extrusion of an aluminum material are arranged vertically in parallel at predetermined intervals. A common top tank is bonded to the top ends of these tubes 42 and a common bottom tank is bonded to the bottom ends to form a coolant water passage. Corrugated fins 43 formed by bending thin sheets of aluminum back and forth into wave shapes are attached and bonded by soldering so as to be sandwiched between the adjoining flat tubes 42 and thereby form air passages.

[0003] In the conventional heater core 41 of this configuration as well, to promote heat exchange between the corrugated fins 43 and the flow of air, sometimes pieces of the corrugated fins 43 are cut and raised to form a large number of for example rectangular or other shaped louvers 44, but the surfaces of the flat tubes 42

are smooth. Further, even at the corrugated fins 43, the parts 45 where the louvers 44 cannot be formed are smooth. Therefore, there is the problem that by just forming louvers 44 at parts of the corrugated fins 43, the heat exchange efficiency between the outer surfaces of the flat tubes 42 and the flow of air at the outsides of the tubes 42 is not improved much at all.

[0004] Further, in a separate conventional type heater core 48 shown in FIG. 5, the smooth surfaces of the flat tubes 42 are sometimes formed with a large number of dimples 46 or formed with a plurality of ribs, but the insides of the dimples 46 or ribs become areas where no air flows, so this is not necessarily effective. Even at the surfaces of the flat tubes 42, at parts bonded with the bent parts 47 of the corrugated fins 43, the solder used for the bonding buries the dimples 46 etc., so at such parts, the dimples 46 etc. do not improve the heat conduction performance between the wall surfaces of the flat tubes 42 and the cooling water (warm water) flowing through the insides.

#### SUMMARY OF THE INVENTION

[0005] An object of the present invention is to provide a heat exchanger such as a radiator, heater core, condenser, or evaporator wherein not only is the heat exchange efficiency improved between fins attached to flat tubes in which a first fluid such as cooling water (warm water) flows and a second fluid such as air flowing in contact with the same, but also novel means are devised so as to improve the heat exchange efficiency between the outer surfaces of the flat tubes themselves through which the first fluid flows and the second fluid flowing at the outside so as to greatly improve the heat exchange efficiency between the first fluid and the second fluid compared with the past.

[0006] According to the present invention, there is

provided a heat exchanger provided with a plurality of flat tubes forming passages for a first fluid inside them and having outside surfaces formed to a wave shape so that passages for a second fluid flowing at the outside of the flat tubes meander in a wave shape and plate-shaped fins in the meandering passages, so when a second fluid such as air flows at the outsides of the flat tubes, it vigorously strikes the outside surfaces of the wave shapes of the flat tubes and is agitated to become turbulent and flows through the meandering passages along the plate-shaped fins. Therefore, the surfaces of the flat tubes are not formed with thick boundary layers such as when a laminar flow of the second fluid flows, so the efficiency of direct heat exchange between the flat tubes and the second fluid is remarkably improved. Needless to say, the heat exchange becomes turbulent, so as a result the shaped fins and second fluid efficiency between the plate-shaped second fluid becomes turbulent, so as a result the heat exchange efficiency between the first fluid and the second fluid is improved.

[0007] The flat tubes may be formed by bending corrugated sheets to tubular shapes or may be formed by assembling pairs of corrugated sheets at their insides. Further, the flat tubes may be fabricated by extrusion so that passages for a first fluid are formed inside.

[0008] If the plate-shaped fins are arranged so that their longitudinal directions become substantially vertical to longitudinal directions of the flat tubes, the directions of the first fluid flowing through the insides of the flat tubes and the second fluid flowing at the outsides of the flat tubes along the wave-shaped passages and the agitating action of the meandering surfaces for the second fluid formed by the wave-shaped surfaces of the flat tubes is strengthened the most, so the efficiency of the heat exchanger can be raised the

most.

[0009] The plate-shaped fins can be formed by bending narrow ribbon-shaped sheets so as to be folded back at the ends in their longitudinal directions. Due to this, it is possible to fabricate multistage fins as single pieces and support them integrally.

[0010] Further, a plurality of the plate-shaped fins may form a fin assembly by being connected through leg parts like a multilevel shelf. In this case, it is also possible to form windows through which the second fluid may pass between adjoining leg parts. The fin assembly may be formed integrally by punching out windows for the second fluid from a single sheet and bending between the leg parts thereby formed and the fins.

[0011] The plate-shaped fins may be bonded to the tops or bottoms of wave-shaped surfaces at the outside surfaces of the flat tubes. If forming the above fin assembly, if the leg parts are bonded to the tops or bottoms of the wave-shaped surfaces formed at the outside surfaces of the flat tubes, not only does bonding become easier, but also the windows for passing the second fluid will not be blocked and the mechanical strength of the heat exchanger as a whole will become higher.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0012] These and other objects and features of the present invention will become clearer from the following description of the preferred embodiments given with reference to the attached drawings, wherein:

FIG. 1 is a cutaway, enlarged perspective view of principal parts of a heater core of a first embodiment of the present invention;

FIG. 2 is a perspective view illustrating the overall configuration of a heater core of an embodiment of a heat exchanger of the present invention as represented by the first embodiment;

FIG. 3 is a perspective view of the state of operation at principal parts of the heater core of the

first embodiment;

FIG. 4 is a cutaway, enlarged perspective view of principal parts of a heater core of the related art;

FIG. 5 is a cutaway, enlarged perspective view of principal parts of another heater core of the related art;

FIG. 6 is a cutaway, enlarged perspective view of principal parts of a heater core of a second embodiment;

FIG. 7 is a cutaway, enlarged perspective view of principal parts of a heater core of a third embodiment; and

FIG. 8 is a perspective view illustrating specific dimensions of principal parts of a heater core of the first embodiment.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] Preferred embodiments of the present invention will be described in detail below while referring to the attached figures.

[0014] The configuration and operation of a heater core 1 for an air-conditioning system to be mounted in an automobile are illustrated in FIG. 1 to FIG. 3 as a first embodiment of a heat exchanger of the present invention. The heater core 1 is used for heating the air in a passenger compartment by the cooling water (warm water) in the internal combustion engine in a not shown air-conditioning system for an automobile. FIG. 1 shows enlarged the characterizing parts (principal parts) of the heater core 1 of the first embodiment, the overall configuration including these parts is illustrated in FIG. 2, and the state of operation of the principal parts is shown in FIG. 3.

[0015] As shown in FIG. 1, in the heater core 1 of the first embodiment, the flat tubes 2 are fabricated by press forming thin sheets of aluminum to tubular shapes having predetermined surface shapes and joining longitudinal direction seams 2a by soldering. A plurality of flat tubes 2 fabricated in this way are arranged

vertically in predetermined intervals, a common inlet tank 3 is joined to the top ends of these tubes 2, and a common outlet tank 4 is joined to the bottom ends of the tubes 2.

[0016] Further, in the illustrated embodiment, an inlet pipe 6 is attached to an inlet of warm water provided at the inlet tank (top tank) 3 and an outlet pipe 7 is attached to an outlet of warm water attached to the outlet tank (bottom tank) 4.

[0017] As clear from FIG. 1 showing the flat tubes 2 cut away at a certain height, the sectional shapes of the flat tubes 2 are not shapes where the arcs 9 of the two ends may be connected by two parallel straight lines, but are shapes where the arcs 9 of the two ends may be connected by two parallel wavy lines of substantially the same shape. Therefore, these flat tubes 2 have surfaces formed in wave shapes in a direction perpendicular to the longitudinal direction (called "wave-shaped surfaces 12"). The wave-shaped surfaces 12 form tops 10 and bottoms 11 of wave shapes extending along the longitudinal direction of the flat tubes 2.

[0018] Further, fins 5 obtained by cutting thin sheets of aluminum into narrow ribbon shapes and bending them into wave shapes with larger amplitudes than the widths are attached so as to fit between adjoining flat tubes 2, then the contact parts of the fins 5 and flat tubes 2 are joined by soldering. Since the surfaces 12 of the flat tubes 2 are wave shaped, when the fins are shaped as ribbons having predetermined widths as in the illustrated embodiment, the contact parts of the flat tubes 2 and fins 5 do not become long linear shapes, but become points or short lines at the tops 10 or bottoms 11 of the wave-shaped surfaces 12 of the flat tubes 2.

[0019] Further, while not essential, in the heater core 1 of the first embodiment, plates 8 for reinforcement are inserted and secured inside the flat tubes 2 with the wave-shaped surfaces 12. As the plates

8, it is possible to use aluminum plates etc. If making the plates contact parts of the arc surfaces 9 of the ends of the flat tubes 2 at their two edges and making them contact the tops 10 and bottoms 11 of the wave-shaped surfaces of the flat tubes 2 at their front surfaces and rear surfaces, it is possible to prevent deformation of the flat tubes 2 most effectively when the pressure of the warm water etc. acts inside the flat tubes.

[0020] Note that in the heater core 1 of the first embodiment, the flat tubes 2, inlet tank 3, outlet tank 4, fins 5, reinforcing plates 8, etc. are all soldered together. For this, the materials of these parts are covered in advance with solder, the parts assembled, then the assembly is heated in a furnace, whereby the solder melts and solidifies to join the parts.

[0021] While not shown, it is also possible to provide partitions in the longitudinal direction of one or both of the inlet tank 3 and outlet tank 4 to divide the insides to a plurality of sections. Due to this, the warm water flows back and forth between the inlet tank (top tank) 3 and outlet tank (bottom tank) 4. The method of flow of the warm water changes depending on the number of partitions and the positions where they are provided, so which of the top tank 3 and bottom tank 4 the inlet pipe 6 and outlet pipe 7 are provided is determined accordingly. Therefore, in the present invention, it is also possible to provide both of the inlet pipe 6 and the outlet pipe 7 at either of the top tank 3 or bottom tank 4.

[0022] When the heater core 1 of the first embodiment is not provided with partitions in the inlet tanks 3 and 4, the high temperature cooling water supplied from a not shown internal combustion engine flows from the inlet pipe 6 to the inside of the inlet tank 3, is distributed to all of the flat tubes 2 in the entire region of the inlet tank 3, and passes through the flat tubes 2 and

flows down to the outlet tank 4. The warm water from which heat has finished being radiated collected at the outlet tank 4 is returned from the outlet pipe 7 to a not shown cooling water sleeve of the internal combustion engine. The high temperature warm water supplied to the inlet tank 3 in this way gives heat to the flow of air flowing through the intervals of the flat tubes 2 or fins 5 while flowing through the flat tubes 2. In the present invention, the fluid such as warm water flowing through the insides of the flat tubes 2 is called the "first fluid" and the fluid such as air flowing outside of the flat tubes 2 is called in general the "second fluid".

[0023] In this way, the heater core 1 of the first embodiment is characterized by the formation of wave shapes at the surfaces 12 of the outsides of the flat tubes 2 when producing the flat tubes 2 by press forming. Therefore, when the warm water (first fluid) flowing through the inlet pipe 6 shown in FIG. 2 to the space in the inlet tank 3 is distributed to the plurality of flat tubes 2 and heat exchange is performed by the heat of the warm water being given to the air (second fluid) flowing in contact with their surfaces from the surfaces of the flat tubes 2 and the surfaces of the plate-shaped fins 5 attached to parts thereof, the air (second fluid) flowing between the flat tubes 2 along the plate-shaped fins 5 forms a meandering flow guided by the wave-shaped surfaces 12 of the flat tubes 2 and the flow is agitated.

[0024] By the air flowing meandering along the wave-shaped surfaces 12 of the flat tubes 2, the air repeatedly strikes the surfaces of the flat tubes 2 and the flow of air is agitated by the wave-shaped surfaces 12 of the flat tubes 2 to form a fine whirlpool-like turbulence, so there is no longer the formation of a thick boundary layer of air which usually is formed on the surfaces of the tubes when the flow of air becomes laminar when the surfaces of the flat tubes 2 are smooth (the boundary layer becomes extremely thin), so the heat



conduction action is promoted, and the heat exchange efficiency between the warm water and air is remarkably improved.

[0025] In this way, the second fluid, that is, air, flows meandering along the wave-shaped surfaces 12 of the flat tubes 2, so to not obstruct the flow, it is preferable that the fins 5 be made elongated overall, there be no folded back parts at the middle, and the flow of air be guided in a direction perpendicular to the longitudinal direction of the flat tubes 2. It is preferable to use even fins which are bent in a wave shape like the fins 5 of the first embodiment if of a shape bent back in the opposite directions at positions close to the side edges of the flat tubes 2.

[0026] FIG. 6 shows principal parts of a heater core 21 as a second embodiment of a heat exchanger of the present invention. The flat tubes 22 forming the passages for warm water in the second embodiment are formed by combining two corrugated sheets 23 and 24 comprised of pluralities of flat tubes 22 together, whereby sectional shapes close to crescent shapes are formed between these corrugated sheets 23 and 24. Exactly the required number of pairs of corrugated sheets 23 and 24 are stacked. A large number of shelves or a fin assembly 25 of a shape like a frame is arranged between the pairs of the corrugated sheets 23 and 24 are joined. The adjoining corrugated sheets 23 and 24. The contact parts of the fin assembly 25 of the second embodiment is comprised of narrow plates arranged in parallel at predetermined intervals in the vertical direction and a large number of leg parts 27 rising (or descending) vertically in the vertical direction from the front edge or rear edge in the width direction of the fins 26. The fin assembly 25 comprised of the large number of shelf-like fins 26 and the large number of leg parts 27

[0027]

connecting these can be fabricated by punching a large number of windows 28 from one aluminum sheet and bending the leg parts 27 at right angles to the fins 26 as if forming steps.

[0028] At this time, if the lengths of the waves of the corrugated sheet 24 and dimensions of the intervals of the adjoining leg parts 27 are made to match so that the tops or bottoms of the corrugated sheets 23 and 24 are soldered together at the time of soldering, the heater core 21 as a whole forms a strong frame structure. Note that while not shown, it is also possible to form the flat tubes 22 by sandwiching flat plates between the pairs of corrugated sheets 23 and 24 and soldering them together. The plates sandwiched between them act to increase the mechanical strength of the flat tubes 22.

[0029] Since the heater core 21 of the second embodiment has this structure, if the first fluid, that is, the warm water, is made to flow from a not shown top tank through the plurality of flat tubes 22 toward a bottom tank as shown by the vertical direction arrows, and the fins 26 as shown by the horizontal direction arrows, the air is guided along the wave-shaped surfaces of the corrugated sheets 23 and 24 and flows in wave-shaped path so as to pass through the windows 28. Due to this, in the same way as the first embodiment, the flow of air vigorously strikes the surfaces of the corrugated sheets 23 and 24 and becomes turbulent, so the thick boundary layer of air is ordinarily formed at the surfaces of the corrugated sheets 23 and 24 is peeled off and heat exchange is performed at a high efficiency between the warm water and air separated by the corrugated sheets 23 and 24.

[0030] FIG. 7 shows the principal parts of a heater core 3 of a third embodiment of a heat exchanger of the present invention. The heater core 31 of the third

embodiment is similar to the heater core 1 of the first embodiment. The characterizing feature of the third embodiment over the first embodiment lies in the fabrication of the flat tubes 32 by extrusion of aluminum. However, the embodiment is the same in that the flat tubes 32 are wave-shaped as a whole, the warm water passages 33 are circular in sectional shape and formed in a plurality, and flat tubes 32 with adjoining fins 43 comprised of sheets bent in the same way as the fins 5 in the first embodiment are joined.

[0031] Since the flat tubes 32 of the third embodiment are fabricated by extrusion, instead of the mechanical strength becoming higher, the thickness seen from the passages 33 of the warm water becomes somewhat greater than the flat tubes 2 of the first embodiment. Due to this, the heat exchange efficiency becomes slightly lower, but the heater core 31 of the third embodiment exhibits substantially the same action and effects as the heater core 1 of the first embodiment.

[0032] Concrete dimensions of the principal parts of the heater core 1 of the first embodiment shown in FIG. 1 will be illustrated in FIG. 8 for reference. In the case of a heater core in an air-conditioning system of an automobile, the dimensions of the parts become small values such as illustrated.

[0033] Note that the heat exchangers of the illustrated embodiments all were heater cores, but the present invention is not limited to heater cores and clearly can also be worked as radiators for radiating heat of cooling water of an internal combustion engine, a condenser or evaporator for cooling in an air-conditioning system, or other heat exchanger.

[0034] While the invention has been described with reference to specific embodiments chosen for purpose of illustration, it should be apparent that numerous modifications could be made thereto by those skilled in the art without departing from the basic concept and

scope of the invention.